

Appendix F - Roof drilling procedure

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1 Introduction

This appendix explains the detailed procedure to be followed for drilling the verification holes in the XT roof. These holes applies to the XTHT's anti-rotation pin. This pin function as a position indicator, as well as preventing the tool from rotating on the spool. It describes the correct approach of drilling these holes. Deviation from this procedure may lead to dangerous operations or high loads applied to the XTHT. Therefore, all personnel included in this work must read this procedure before starting the operation.

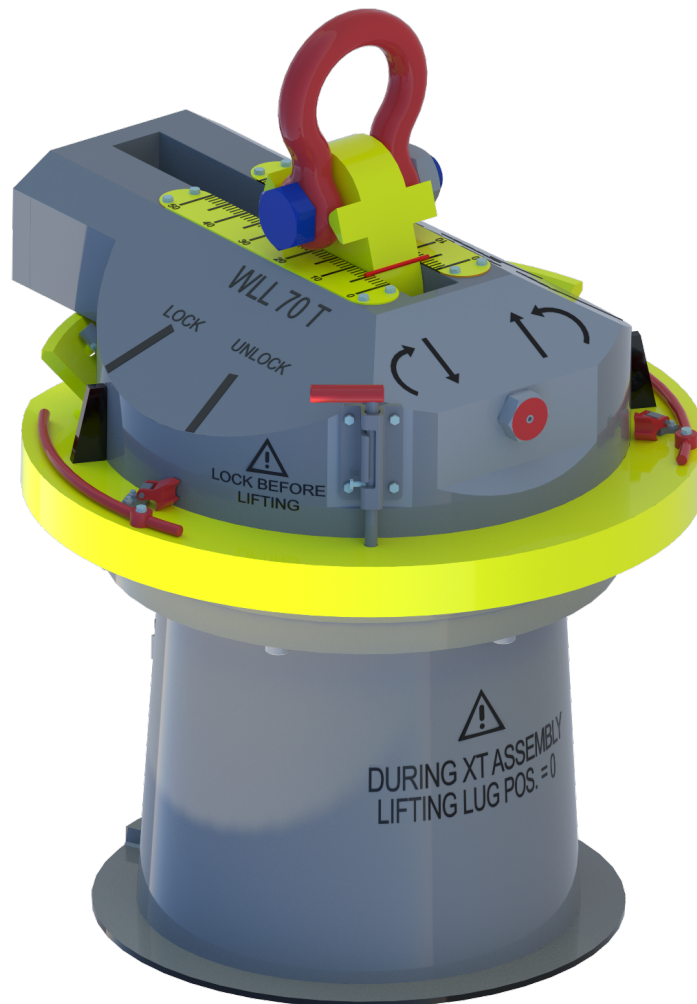
Reference documents:

- Main report
- Appendix A - Design basis
- Appendix E - Angle offset and torque calculations

2 Important information

In general, the Xmas tree handling tool (XTHT) is used to lift and handle the a subsea xmas tree. The tool is shown in Figure 1a and has the possibility to lift in several lifting configurations, which are as follows:

- Complete XT
- Without FCM
- Without SCM
- Without FCM and SCM



(a) Xmas tree handling tool

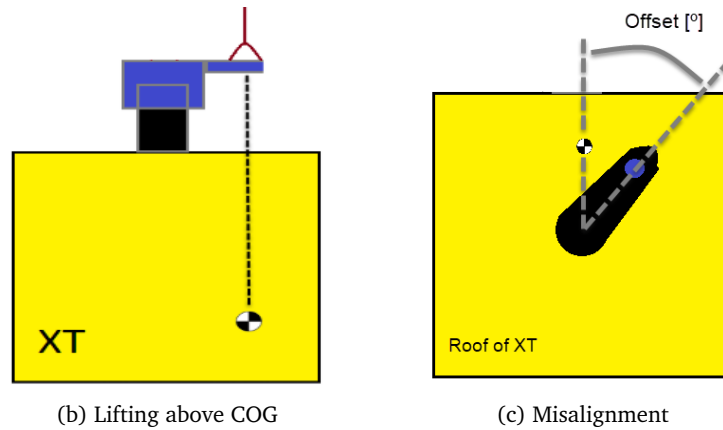
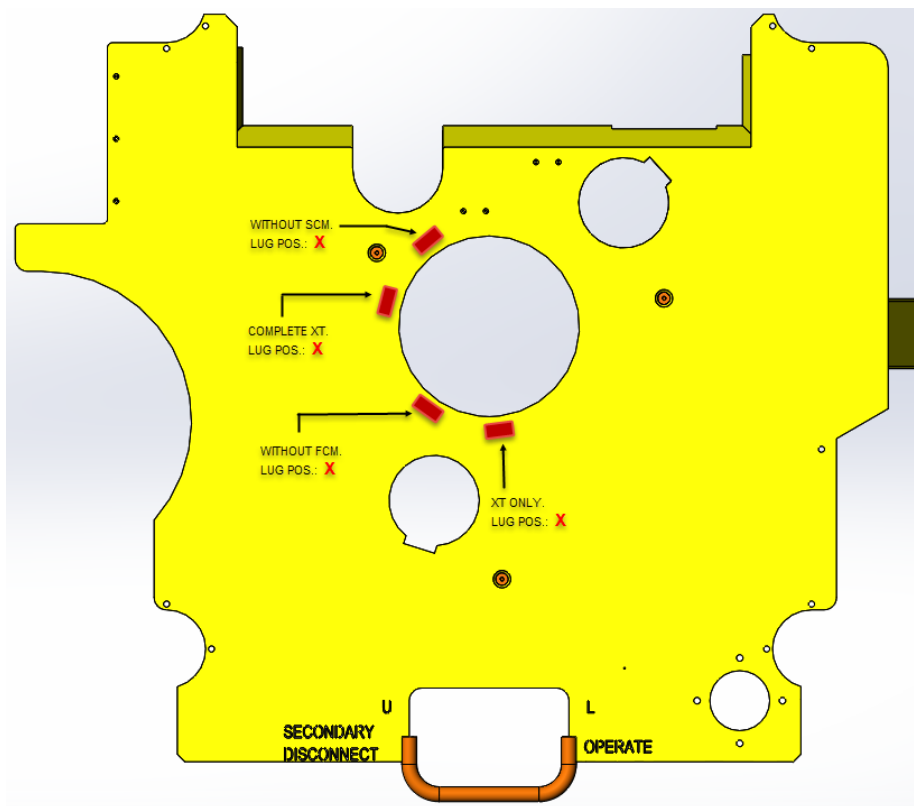


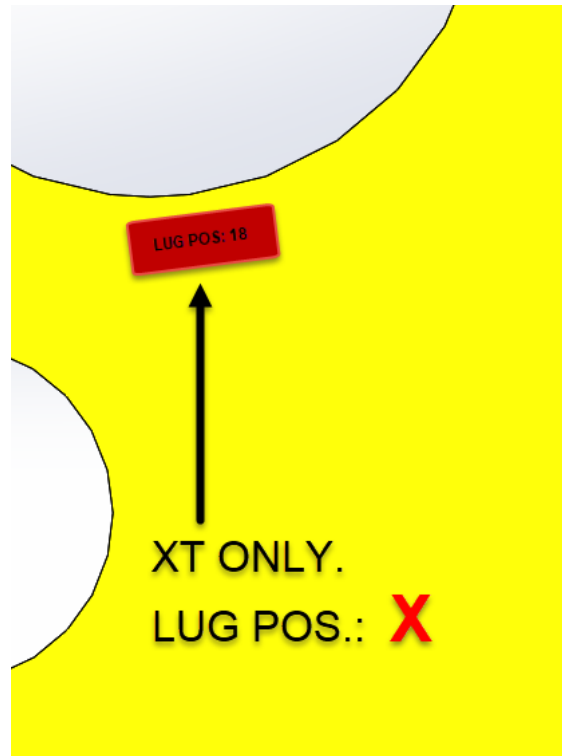
Figure 1: The XTHT and different illustrations

The tool intends to lift above center of gravity in the XT assembly, as Figure 1b shows. If the tool is not aligned properly towards COG, a torque will be generated and try to rotate the tool at the spool. Figure 1c illustrates the misalignment. The values of generated torque in the different angle offset is covered in appendix E.

Figure shows an example of a XT roof, marked with red rectangles which represent the drilling areas. The length off the retangles is 59mm. If the holes is drilled within this area, the XT would have a maximum tilt requirement at 1.7° . These calculations and requirement is based on appendix A and E.



(a) XT roof with temporary markings.



(b) Close up view of "ONLY XT" configuration.

Figure 2: The roof and its temporary markings to indicate drill area.

The drill area is based on the theoretical COG location calculated by SolidWorks, which could have some deviation from the actual location. To ensure sufficient tilt angle, pre-lifts and measuring of the tilt is necessary prior to drilling.

The anti-rotation pin at the XTHT function as a rotation barrier. However, this pin is not in function before the holes in the roof are drilled. The calculation sheet in appendix E shows the safety against rotation as the pin is not present. The friction in the locking mechanism is the only working resistance, where the sheet shows that the safety factor is below one already at an angle offset at 2° . It's important to mentioned that is a worst case scenario during the following conditions:

- Distance down to COG: 2m.
- Off center distance: 0.5m
- XT weight: 70 tonnes
- Friction coefficient: 0.02

The friction coefficient is very conservative and an increment of this would drastically change the safety factor. According to the calculation sheet, would a friction coefficient at 0.45 result in a safety factor which does not go below one. A safety factor at two is first achieved at 32° offset, as an example. Figure 4 in the end of this procedure gives a section of the calculation sheet. James F. Sullivan states a typical friction coefficient as 0.7, on a dry steel on steel connection, sourced from his book "Technical Physics", USA: Wiley, 1988: 204.

2.1 Safety

This section covers important actions and precautions which needs to be present in the work described in this procedure.

It needs to be early stated that due to the lack of anti-rotation barriers in the pre-lifts, **extreme caution** shall be exercised during these lifting operations.

2.1.1 Safety responsibility and personnel duties

The following list show some general safety information to the operator. Additional to this, the Aker Solutions "Just rules" policy must be adhered.

- The assigned supervisor is responsible to ensure that all tasks are safely assessed and that the risk of injury or accident is as low as possible
- High caution shall be exercised during all lifting operations.
- Any personnel may and shall stop the work if safety is compromised in any way
- All incidents, near misses, unsafe acts etc. shall be reported on own forms to increase awareness and initiate preventive measures to avoid accidents.
- Use required PPE (Personal Protective Equipment).
- Use applicable "Work at height" safety equipment.
- Use applicable protection when using chemicals, which shall be stated at the containers label.

2.1.2 Safety barrier and signs

- The lifting area shall be enclosed with warning bands, with intention to avoid other personnel to enter.
- Display the workshops relevant safety signs in and around the operation area.
- The personnel must observe and adhere to all safety signs.

2.1.3 Appearance of safety notices

There are three types of notices used in this document; Danger, Warning and Caution.



Danger: Description of imminent hazard. Not following the instruction will result in serious injury or death



Warning: Description of hazard. Not following the instruction could result in serious injury or death.



Caution: Description of hazard. There is a risk of minor injuries.

2.1.4 Safe Job Analysis (SJA)

Prior to pre-lifts of the XT, a safe job analysis should be performed. All included personnel shall participate.

2.2 Markings

The marked drilling area and the "X" are labels and taped onto the roof and shall be removed after drilling. The "X" represent where the lifting lug position should be painted on after the pre-lifting is finished. The paintwork should be done in compliance with Aker Solutions painting and colour regulations. Figure 3 shows the markings one more time. See Figure 2a for the whole roof.

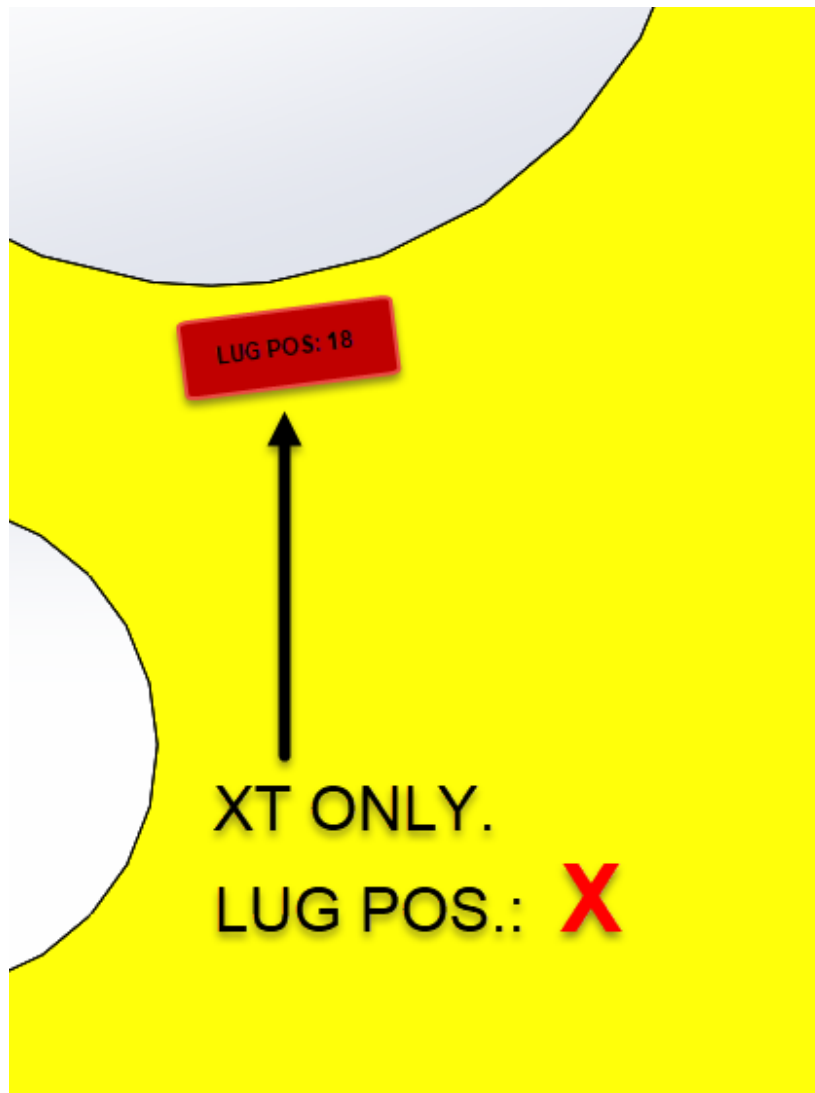


Figure 3: Red labels taped onto the roof

2.3 Equipment list




The following list presented the required equipment to perform the job:


- A magnetic digital level
- Appropriate drill machine
- Drill bit sizes:
 1. Center drill bit
 2. Pre-drill no.1: 5mm
 3. Pre-drill no.2: 15mm
 4. Final drill bit size: 28mm
- Round file
- Painting according to Aker Solutions colour regulations.
- Paintbrush or spray painting
- Methylated spirits or other cleaning products
- Rags
- PPE and other relevant safety equipment

2.4 Deviations

Deviation from this procedure, drawings or specifications shall be approved. Contact responsible engineer if deviations occur.

3 Procedure

Step	Instructions	Initials
1	Prepare the work station and perform the SJA with the involved personnel.	
2	<p>Clean the H4-profile on the spool and the locking dogs at the XTHT. Ensure a dry and clean connection in this interface.</p> <div>  <p><i>Not following these step will result in serious injury or death. A wet or greased spool will contributes to low friction in the connection. There is an huge risk of the tool to rotate on the spool as the lift is performed. The rotating motion would escalate and the huge mass of the XT could crush into people or the surroundings.</i></p> </div>	
3	Lift the XTHT onto the spool	
4	<p>Align the tool towards the correct configuration and screw the lifting lug to the position which is specified on the markings. Figure 3 gives an example.</p> <div>  <p><i>Aligning the tool towards the wrong configuration would result in high torque to the tool and risk of it to start rotating. However would such a large misalignment result in large tilt, which would be detected early in the lifting sequence and the lift can be cancelled.</i></p> </div>	
5	Lock the XTHT to the XT by the locking ring. Secure the position by the secondary lock pin.	
6	<p>Perform test lift and measure the tilt angle with an magnetic level. If the angle is insufficient, cancel the lift and tune the tool angle and/or the lifting lug position in the required direction.</p> <div>  <p><i>The lift need to be carried out in slow motion, so any improbable high tilt and rotation hazard can be detected at a early stage. The level should also be magnetic, reducing the contact time with the lifted XT. Extreme caution shall be exercised when closing up to and touching the lifted XT.</i></p> </div>	

Step	Instructions	Initials
7	When the tilt is within the requirement, do the following: <ol style="list-style-type: none"> 1. Mark a point at the label as verification for step no. 9. 2. Note the lifting lugs off-center distance: 	
8	Detach the XTHT and remove tool if this necessary considering the need of space during drilling.	
9	Drill the hole with the equipment mentioned in section 2.3.  <i>Be aware of rotating motion of the drilling equipment and secure it to the roof using fall protection equipment</i>	
10	Perform a final test lift with the anti-rotation pin penetrated to the new hole.	
11	Remove the red markings/labels.	
12	Last finish work: <ol style="list-style-type: none"> 1. Paint the noted lifting lug position onto the roof. 2. Paint the black arrow towards the new hole, see Figure 3. 3. Round off the edges in the new hole using a file. 4. Paint the drilled whole to ensure protection against protection. 	
13	Repeat the procedure for the last three configurations	

4 Calculation sheet

The next page shows a section clip from the calculation sheet. Note the green line which represent the data as the XT tilt 1.7° , which is the requirement to maximum tilt, referring to appendix A. The little box above the sheet contains the variables and basis for the formulas in the sheet, as well as the angle offset represented by α .

For symbol explanation and derivation of the calculations, see appendix E - Angle offset and torque calculations.

Position down to COG		2	meter
Max off center lift		0.5	meter
XT weight		70	tonnes
Friction coefficient		0.45	

α [°]	ϕ [°]	θ [°]	O [mm]	β [°]	Normal force [N]	Rotational force [N]	Torque [Nm]	Safety	Force at anti-rotatin pin [N]
0	0.00	0.00	0.0	0.00	700000	0	0		0
1	0.00	0.25	8.7	0.25	699993	3054	1527	61.9	3054
2	0.01	0.50	17.5	0.50	699973	6107	3054	30.9	6107
3	0.02	0.75	26.2	0.75	699940	9158	4579	20.6	9158
4	0.03	1.00	34.9	1.00	699893	12206	6103	15.5	12206
5	0.05	1.25	43.6	1.25	699834	15249	7624	12.4	15249
6.81	0.10	1.70	59.4	1.70	699692	20742	10371	9.1	20742
7	0.11	1.75	61.0	1.75	699674	21317	10659	8.9	21317
8	0.14	1.99	69.8	2.00	699575	24341	12170	7.8	24341
9	0.18	2.24	78.5	2.25	699462	27355	13678	6.9	27355
10	0.22	2.49	87.2	2.50	699336	30360	15180	6.2	30360
15	0.49	3.70	130.5	3.73	698514	45202	22601	4.2	45202
20	0.86	4.89	173.6	4.96	697376	59649	29824	3.2	59649
25	1.34	6.03	216.4	6.18	695937	73585	36793	2.6	73585
30	1.92	7.13	258.8	7.37	694211	86908	43454	2.2	86908
35	2.59	8.16	300.7	8.55	692220	99525	49762	1.9	99525
40	3.35	9.13	342.0	9.70	689984	111351	55676	1.7	111351
45	4.19	10.02	382.7	10.83	687527	122311	61155	1.5	122311
50	5.10	10.84	422.6	11.93	684877	132330	66165	1.4	132330
55	6.09	11.57	461.7	13.00	682058	141335	70668	1.3	141335
60	7.13	12.22	500.0	14.04	679100	149253	74627	1.2	149253

Figure 4: Section clip from calculation sheet